An acceleration technique for the radioelectric coverage prediction in small and microcell configurations

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AN ACCELERATION TECHNIQUE FOR THE RADIOELECTRIC COVERAGE PREDICTION IN SMALL AND MICROCELL CONFIGURATIONS

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1. ABSTRACT

The purpose of this work is to optimise the necessary computation time for the coverage zone prediction. Several approaches exist to reduce the calculation time; they consist in simplifying the complexity of the used propagation model.
Here, our method is different but complementary of the previous approaches. Indeed, it is independent of the propagation model and tries to reduce the number of application points of the considered model for the coverage prediction. Thus, the performances of our optimised method in term of accuracy and computation time is presented in this article.

2. INTRODUCTION

This study joins with the frame of the works connected to the studies of propagation for the radiocommunication mobile systems.

The planning and the display of the set up systems put technical and economic problems. Whatever is the considered system, a good accuracy of the coverage zone is necessary. For the study of a geographic site, the classic technique of a coverage zone prediction consists in applying a propagation model in various defined positions according to a constant spatial step. This step is generally to some meters in urban environment. However, this method leads to an important computation time, indeed prohibitive in complex geographic environments and with complex propagation models.

Thus, the acceleration technique in computation time proposed for the radio coverage zone prediction is based on the hypothesis specified in the paragraph 3. It allows to apply a propagation model on some points only of the environment, contrary to the classical prediction methods.

To verify this hypothesis and in this way apply our optimised method, it is necessary to dispose of two tools presented in the paragraph 4. The first is a segmentation tool based on the wavelets maxima. It allows to detect the significant behaviour changing of measured signals on a mobile route. The second tool, the heart of the optimised method, is an electromagnetic analysis software developed in the laboratory. It implements the propagation mechanisms inherent to the environment and the transmitter position.

Then in the last paragraph, the algorithm allowing to verify our hypothesis is described thank to a simple example and an evaluation of the performances is given for a micro cell configuration.

3. HYPOTHESIS

Thanks to the analysis of many radioelectric signals received at the time of measurements campaigns and considering the modelisation of the electromagnetic phenomena, our optimised method is based on the following hypothesis:
Hypothesis: The variations of a received signal on a mobile route are homogeneous for a same combination of electromagnetic interactions (the wave in line of sight, when it exits, must be integrated to the combination).

Thus, the set of points for whom the received signal is associated to a same combination of electromagnetic interactions leads to delimit a spatial region. Each spatial region is characterised by a stationary received signal (WSSUS): the variation of the mean power is small.

So, we can deduce that the studied geographic zone is a partition composed to different spatial regions where in the received signal has a homogeneous behaviour. So, to go from one region to another amounts to consider the slow variations of received signals [1]. The Figure 1 allows to illustrate this hypothesis on a schematic example.

Considering the transmitter position as the Figure 1 (a) shows it, the application of the electromagnetic wave propagation laws leads to different regions. Each of them is characterised by a combination of electromagnetic interactions: (1) visibility, (2) visibility plus reflection, (3) diffraction. Thus, the received signal on the mobile route of the Figure 1(b) presents significant variations at the points P_{1s}, and P_{2s} corresponding to the limits of the different stationary regions, due to the electromagnetic phenomena, which are crossed by the mobile route (P_{1a}=P_{1s}, P_{2a}=P_{2s}).

Considering this hypothesis, to optimise the computation time of the coverage zone, it is possible to apply a propagation model on a few points of each region, and to extrapolate the result to the whole region. Thus, the number of application points necessary to the coverage prediction is less than this one of the classical technique.

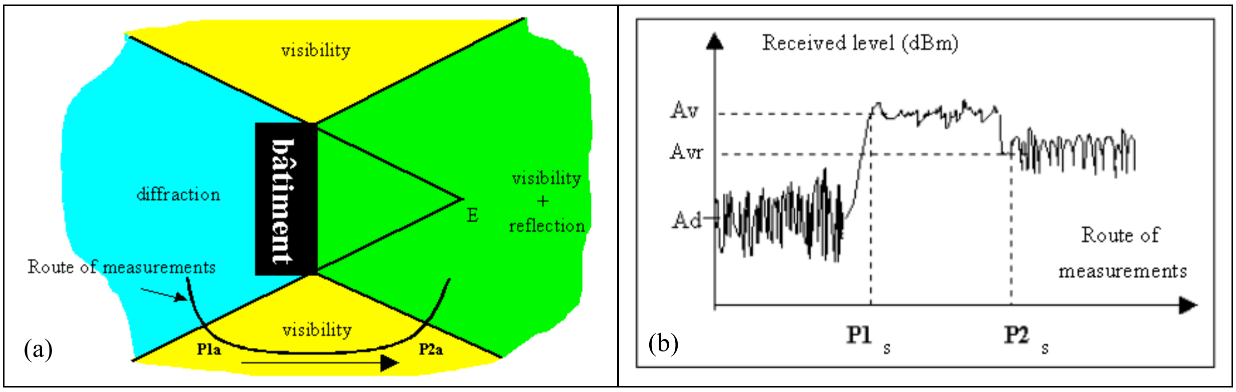

Figure 1 – (a) Spatial partition – (b) Schematic signal received on the route of measurements

Two tools are necessaries to verify our hypothesis: a segmentation technique allowing to detect the variations of signals received on predefined mobile route and an electromagnetic analysis of the propagation environment.

4. THE TOOLS

4.1. *Segmentation by Wavelets maxima*

The wavelets maxima constitutes a particular wavelets transform based on the multiscale analysis and the filter banks theory [2]. Each scale corresponds to a particular frequency band; so, the greater is the scale, the smaller are the frequencies. From this comes the fact that we automatically smooth the signal as we probe its low frequencies. The function smoothing the signal is called smoothing function ($\zeta(d)$), where d is the spatial variable. It allows to compute the next scale.

If the wavelet $\psi^1(d)$ is defined as the first-order derivative of the smoothing function, the local extrema of the wavelets transform correspond to the discontinuities of a signal at each scale. These extrema are called wavelets maxima.
The wavelets function $\psi^1(t)$ is defined by **(1)**:

$$\psi_e^1(d) = \frac{1}{e}\psi^1(\frac{d}{e}) \qquad \textbf{(1)}$$

where $\psi_e^1(d)$ is the dilatation by the scaling factor *e* of the wavelet function $\psi^1(d)$.

The wavelet transform of a signal s(d) at the scale *e* is defined by **(2)**:

$$W_e^1 s(d) = (e\frac{ds}{dt}) * \zeta_e(d) \qquad \textbf{(2)}$$

In others words, the wavelets transform $W_e^1 s(d)$ defined in **(2)** is the first derivative of the signal followed by a smoothing by the function $\zeta_e(d)$ at the scale e. The small fluctuations or rapid variations of s(d) disappear progressively as the scale becomes high. Thus the extrema are due to the slow variations of the signal. For example, thanks to this wavelet, it is possible to identify automatically the three intervals associated with the significant variations of the signal of the Figure 1(b).

4.2. Electromagnetic analysis

The electromagnetic analysis can be split up into three phases: the waves propagation, the spatial cut-out of the geographic zone and the grouping of regions having near physical characteristics. Each region of the obtained partition is characterised by a combination of interactions (diffraction, reflection and line of sight).

We have chosen to construct three independent modules: one of them is based on a study in the horizontal plan (2DH), an other situates the study in a set of vertical plans (2DV) and the last consists in combining the informations given by the two precedent cases.

Whatever the version considered, the software is based on a search of optic boundaries. The principle consists in determining the reflective faces and the diffractive edges of the environment. In the case of a horizontal plan analysis, the reflection and diffraction phenomena produce the effects illustrated by the Figure 2 (a) and (b).

Concerning the electromagnetic analysis version developed in vertical, the approach is the same that the previous, but the execution is more complicated: previously, the partition due to the horizontal study was obtained thank to an unique horizontal plan; in the vertical case, the partition must traduce, for a receiver height equal to 1.5m, the influence of the propagation phenomena which exist in the vertical planes. This partition is obtained by the combination of a great number of vertical plans informations extract at a receiver height equal to 1.5m. This approach is illustrates by the Figure 3 (a) and (b).

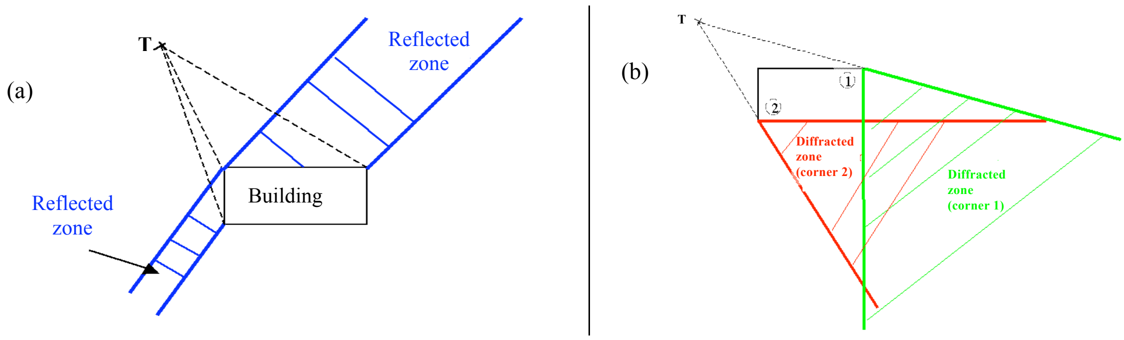

Figure 2: 2DH module : (a) – Reflected zones due to a building ; (b) – Diffracted zones due to a building

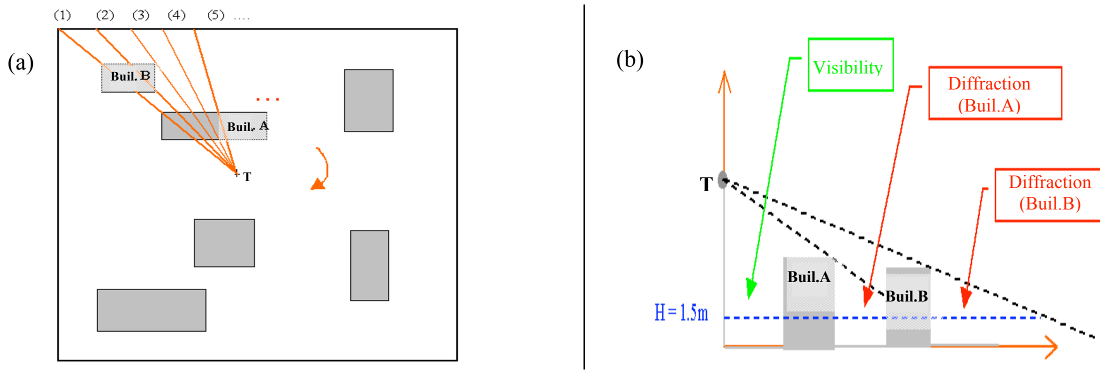

Figure 3: 2DV module : (a) – Regular sweeping of the studied environment by vertical plans ;

(b) – Electromagnetic analysis in a vertical plan.

The objective of the electromagnetic analysis is to give a partition which leads to a coverage computation. Moreover, the calculation is built on the determination of the significant slow variations of received signals (§3). So, the partition must be constitute uniquely by the regions which lead to the such variations. Thus, it is indispensable to establish a relation between the interaction combinations identified by the electromagnetic analysis and the mean power of the signal received in the regions of the partition as the figure 1 shows it. The last point necessitates to define a hierarchy of the influence of the different electromagnetic interactions in order to determine the predominant combination, in terms of received energetic level, for each region of the partition. Thus for example, a region constituted by line of sight + reflected waves will considered as being a region in line of sight. On such considerations and after groupings of contiguous regions having same characteristics, we obtain, for the example of the Figure 2, the significant partition of the Figure 4.

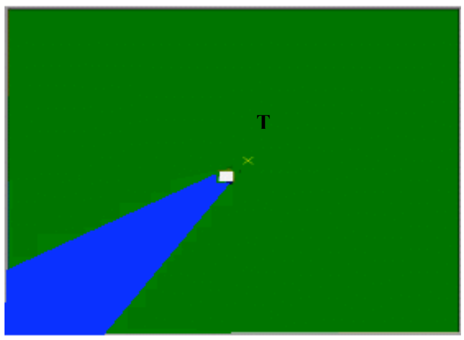

Figure 4: Partition due to the electromagnetic analysis after grouping.

Concerning the electromagnetic analysis version realised in 2.5D, the partition is due to the combination of horizontal and vertical partitions, and the previous groupings of contiguous regions presenting the same electromagnetic characteristics is also realised.

Whatever the considered version, the electromagnetic analysis uses as input parameters data characterising the propagation environment. These last are defined by data bases of the National Geographic Institute (N.G.I.) and give in 3D the ground and the over ground. Moreover, the software is also parameterised by the number and the nature of electromagnetic interactions (diffraction and reflection) taken into account for the computation of the partition. These parameters are essentials because they intervene directly on the cut-out of the partition. So, they are estimated in the last paragraph and the performances of our optimised method evaluated.

5. CHECK OF THE HYPOTHESIS AND EVALUATION OF THE PERFORMANCES

At first the hypothesis advanced in the paragraph 3 will be verified, and in a second time we will present the results of our method in terms of accuracy and computation time.

5.1. Check of the hypothesis

The purpose of this paragraph is to verify experimentally the validity of the hypothesis formulated in the paragraph 3 which is the base of our method of optimisation for the prediction of coverage zone. Let us remind that this hypothesis is that there is a very strong correlation between the slow variations of measured signals and the propagation mechanisms of the radio electric waves. The technique used to validate this hypothesis consists in verifying, on a great number of signals, that the segmentation provides by our algorithm (§ 4.1) corresponds effectively to the spatial partition obtained by the electromagnetic analysis software (§ 4.2). The flowchart of this technique is proposed on the Figure 5.

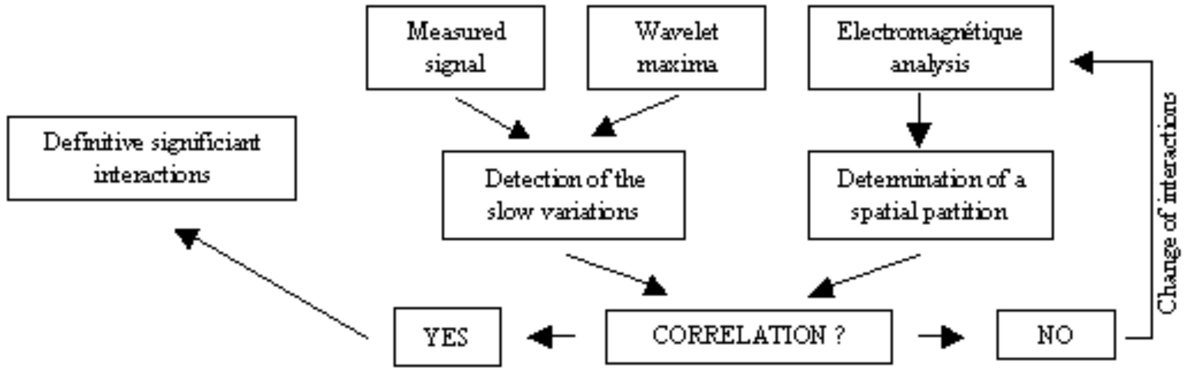

Figure 5: Flowchart of the validation phase of the hypothesis for a route of measurements.

In the stemming of this algorithm, one gets back the optimal electromagnetic combination of interactions for a given environment. Once the partitionment of the environment calculated with the correct parameters, it remains to apply the propagation model on only some points by partition elements and to extrapolate correctly the level calculated by this one in the whole element.

5.2. Evaluation of the performances

It was showed that for a microcell configuration in a dense urban environment, a study in a 2DH plan gives the best results. The next example is in this configuration. A study showed that this minimal number of application points of the propagation model is equal to two. One calculates so the average of the loss estimated by the model for every element and one affects this value to all the points of the element. This method giving inferior results in regions in direct visibility of the transmitter, we have chosen to resort to a formula of loss in free space for these.

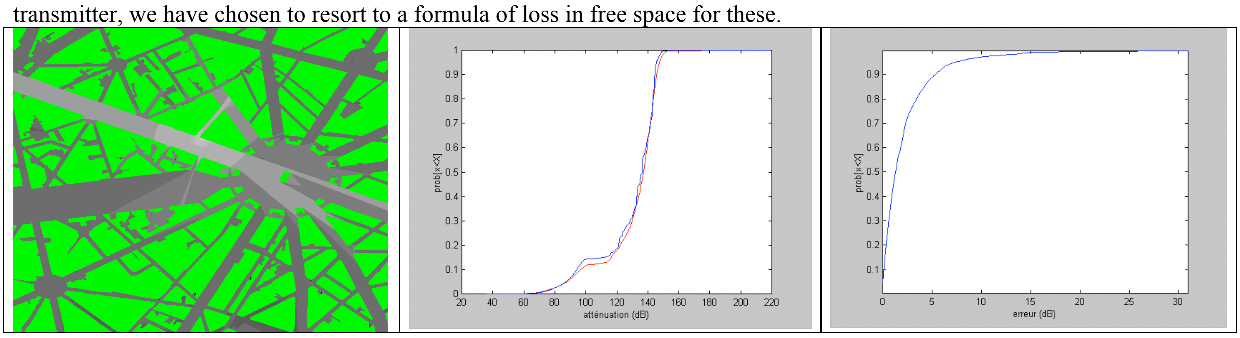

Figure 6: -(a) coverage zone -(b) cumulative functions of classical coverage (red) and optimised coverage (blue) -(c) cumulative function of TOPASE estimated error.

These results of the Figure 6 were obtained with a combination of 0 reflection and 4 diffractions. The Figure 6.c shows that 50 % errors are inferior at 1.46 dB and 90 % of errors are inferior at 5.53 dB.

As regards the computation time, we obtained an reduction factor of 4.49 with a 2D scalar model. But we reduced the number of points of application of the propagation model of 80 %. So to conclude, it is important to notice that the more the used propagation model will be complex, the more the reduction factor will be important.

Thanks

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